Sborník vědeckých prací Vysoké školy báňské – Technické univerzity Ostrava
číslo 1, rok 2008, ročník LI, řada hutnická
článek č. 1377

THE CHOICE OF LONGITUDINAL CURVATURE OF TOOTH IN GLEASON SYSTEM IN CONTEXT OF HPG KLINGELNBERG FINISHING PROCESS

P. SKAWIŃSKI

Institute of Machine Design Fundamentals, Faculty of Automotive and Construction Machinery Engineering of Warsaw University of Technology, Warsaw, Poland, psk@simr.pw.edu.pl

ABSTRACT: This paper had been inspired by technological problems on spiral bevel gears at MAAG-Gears Elblag (Poland), which produce power gears unit (for ex. 200 KW and more). MAAG Gears Elblag has two big milling machine for spiral bevel gear: 5A284 (Saratow) and Gleason No. 655. Both machines work in the Gleason technology. Technical status of those machine do not allow to manufacture the gears in 8 and 7 class of accuracy, which is obligatory needed to correct work of gear boxes. The spiral bevel gears in those classes are produced in cooperation with Klingelnberg (Germany). This situation much more expand delivery and production cycle time. Production cycle is possible to make shorter by separation of the rough operation of cutting teeth in Elblag (Gleason system) and finish operation in Klingelnberg (Germany). This paper will be the trial of the connecting two different technologes: Gleason system as rough operation and Klingelnberg system as a finish operation.

KEY WORDS: spiral bevel gears, design, technology

1. INTRODUCTION

The research works of Spiral Bevel Technology Group (SBTG) concentrate on design and technology of spiral and hypoid bevel gears. Computer program KONTEPS, as developed by SBTG, is the base of computerized integration of design and manufacturing of spiral bevel and hypoid gears. KONTEPS includes design (geometrical, cutter head and blades, and stress analysis calculations) and technological calculations (base technology and machine set up). This program was written for Gleason, Oerlikon and Klingelnberg system for generated and formate gears. Calculations include spiral bevel gears, hypoid bevel gears and straight gears. Calculations executed in KONTEPS are the base for cutting simulation and the 3D models are generated in CAD/CAM/CAE environment (for example Unigraphics, Catia) [1], [2], [3]. The 3D surface or solid models are used to tooth contact analysis and in this case, for comparison of two different models: one Klingelnberg gear model and second Gleason gear model. This comparison allows to analyse both models from technological point of view, taking into consideration the possibility of linking operations rough and finish or inversely. In this case the special application (in Unigraphic environment written in Grip language) connected with KONTEPS has allowed to compare models and draw the conclusions concerning the cutter radiuses which had been engaged to cutting operation in Klingelnberg and Gleason systems.

2. COMPARISON OF GLEASON AND KLINGELNBERG SYSTEMS

The Gleason system characterizes single indexing method, tapered tooth depth and spiral tooth line as an effect of using face cutter head with outside and inside blades situated on constant radiuses. Generally, Gleason gears has tapered tooth but is possible to obtain by tilted root line method equidepth teeth (Fig. 1). This type of teeth is used in piece and low-volume production because the correction pressure angle is equal zero. It means, that the gears haven't any bias changes. Design of this type of gears is rather compromise for correction of pressure angle ($\Delta\alpha = 0$) between cutter radius, spiral angle and undercut on the inner cone distance. Gear is milled by alternate cutter head. For pinion manufacturing is engaged alternate cutter with point width for rough operation, which responds cutter point radiuses for concave and convex sides of tooth or two cutters: one alternate cutter for one of the tooth sides and second one-sided cutter for finishing operation rough milled flank. Manufacturing process of gear needs one set-up of machine. Pinion is milled in two machine set-ups: for concave and convex sides (Fig.3a). The crowning method is connected with different radiuses of pinion cutters related to cutter for gear.

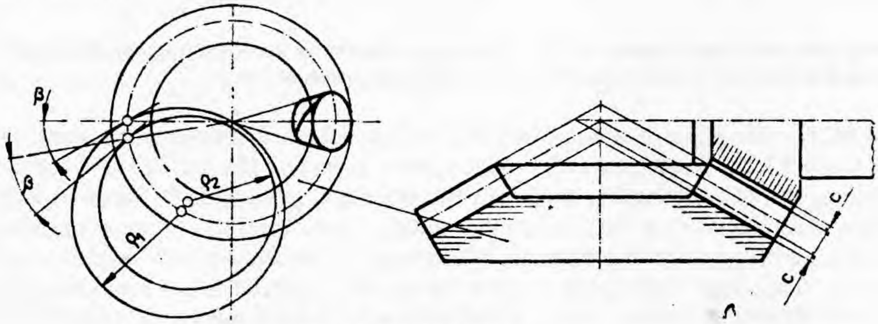

Fig.1: Gleason gear

Klingelnberg system characterizes continuous indexing, equidepth tooth and spiral tooth line as epicycloid (Fig.2). Zyklopalloid method needs two-sided cutters and two machine set-ups: one for gear and one for pinion. The crowning method depend on cutter construction. Klingelnberg cutters has two-pieces body and the eccentricity between them gives the quantity of crowning. Basic set-up for gear and pinion is shown on Fig. 3b.

The kinematics conditions of gears manufacturing in Gleason and Klingelnberg systems are different. Although the gears are from different systems, the fundamental different refer to curvature radiuses of tooth sides: piece of circle on the face (Gleason) and epicycloid (Klingelnberg).

For linking operations from two different systems is very important the choice of cutter radiuses, that the difference of curvature radiuses measured on the both sides of the face width, give the minimum value. It means the minimum stock allowance and minimum number of cutting passes are guaranteed. Particularly, if the HPG process is engaged for finishing operation. But this process is recommended for these gears, because the thermal deformations after hardening will removed. The rough operation can be done in Gleason system and finish operation in Klingelnberg system but reverse situation is also acceptable.

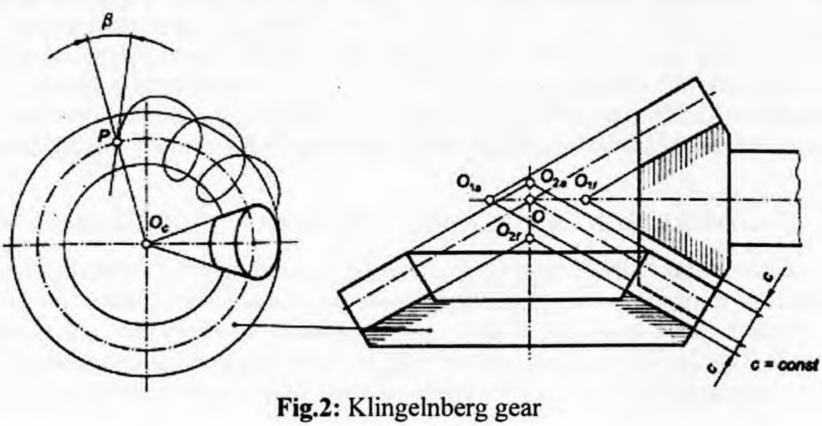

Fig.2: Klingelnberg gear

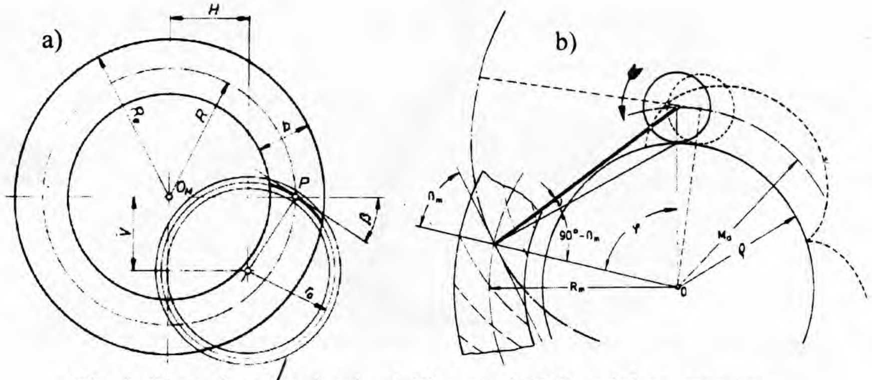

Fig. 3: The rule of cutting in a) Gleason, b) Klingelnberg systems.

3. CALCULATIONS AND 3D MODEL OF GEARS

All calculations had been done in KONTEPS system for ratio 17/54 for Zyklopalloid and Gleason. Because finishing operation is made by HPG process (Klingelnberg) on AMK 855 machine, then calculation had been done for two cutter radiuses: 210 1 218 mm. It allows better select Gleason cutter diameter for rough operation. As a beginning value had been taken nominal diameter equal 18 inches. Several Gleason's calculations and several cutting simulations had been done. For each case had been checked the differences in curvature radiuses. Based on analyses of all cases (below are presented several screens), were determined such cutter diameter (radius) which gives the best approximation. Based on technological calculations and setting of virtual machine according to rules shown on Fig.3, had been generated 3D models: solid and surface (only tooth sides). Putting on Gleason model the surface Klingelnberg gear model in common coordinates, is possible to determine which radius approximate the curvature of tooth with minimum deviation value.

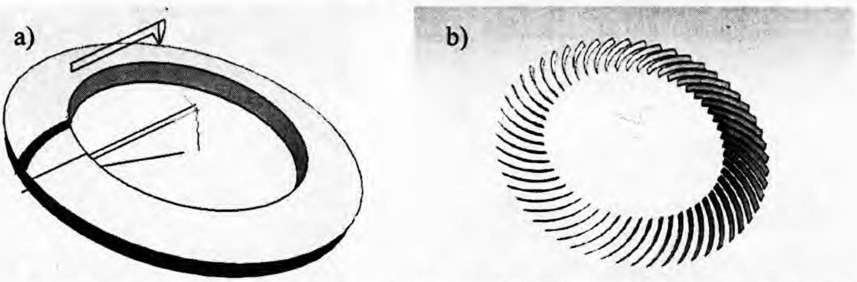

Fig.4: 3D models of gears: a) Gleason- solid model, b)Klingelnberg – surface model

4. CUTTER RADIUS SELECTION

The Unigraphics environment were used to comparison of curvature radiuses for both 3D models. The screen showed below which had been chosen from many trials (Fig. 5), illustrate the common areas (shaded) and the differences, especially on the both sides of face width. Fig.5 shows the solution where differences on the both sides of face allow to cut gears in HPG process (after hardening). For this case, finishing cutting will made in several passes (about nine).

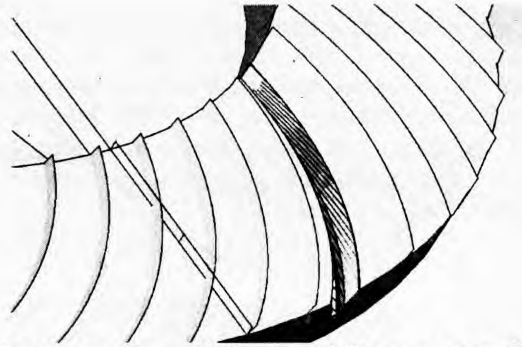

Fig.7: Klingelnberg cutter radius r = 210 mm and Gleason cutter diameter 18"(420.0 mm)

Deviation on the pitch cone on the outside and inside of face width: 0.823/0.937 mm

5. MEASUREMENTS AND CONCLUSIONS

Independently from virtual cutting simulation and comparison, had been done the measurements on the CMM (Fig. 8). For example, the results of measurements of convex side were shown on Fig. 9. Deviations listed on the topography of tooth are very closely to computer simulations. Summarizing, based on calculations, cutting simulations, experimental verification and analyses, is possible to link rough and finish operations in different systems: rough in Gleason system, finish operation in Klingelnberg system. The same conclusion refer to another situation: rough cutting by Zyklopalloid method and finish cut in Gleason system. Very important condition is an assurance minimum stock allowance on the toe and heel of tooth. The range of the chip thickness in HPG process is 0.05 – 0.09 mm for one pass, than the quantity of stock allowance determines the time of finishing cutting and cost.

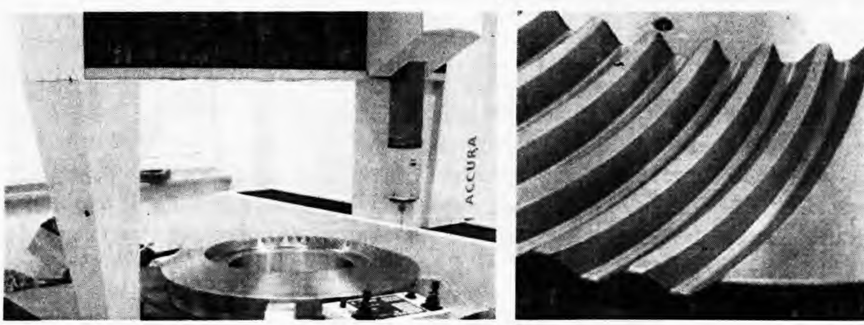

Fig 8: Measurements on the CMM machine

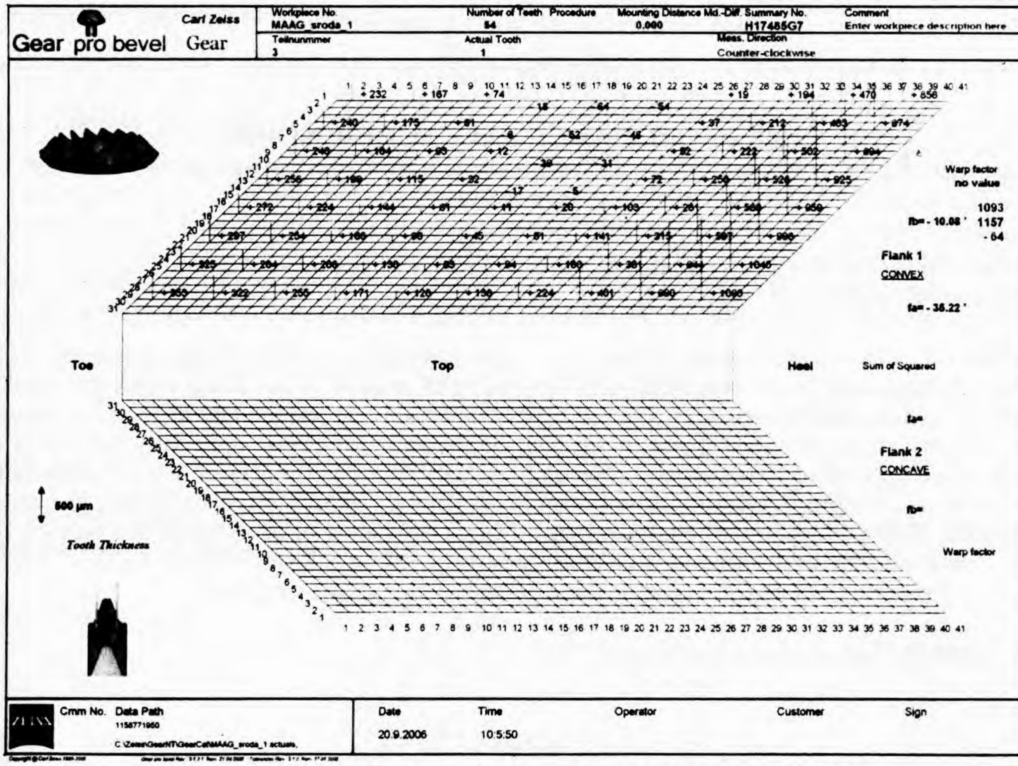

Fig. 9: Flank topography of convex side (after rough operation)

6. REFERENCES

[1] DUDAS L.: Surface constructor – a tool in investigation of gear surface connection", Computer Integrated manufacturing. Advanced Design and Management. WNT, 2003, Warsaw, Poland.

[2] SKAWIŃSKI P., SIEMIŃSKi P.: "Tooth contact generation of spiral bevel gear in environment of CAD/CAM/CAE system" – "Generowanie w środowisku systemów CAD/CAM/CAE śladu współpracy uzębienia przekładni stożkowej o krzywoliniowej linii zeba", Priority Program "New Technologies", Warsaw 2002, Poland.

[3] SKAWIŃSKI P., SIEMIŃSKI P.: "Parametric solid modeling of spiral bevel gearsand tooth contact generation". Computer Integrated manufacturing. Advanced Design and Management. WNT, 2003, Warsaw, Poland.

[4] SKAWIŃSKI P., SIEMIŃSKI P., JĘDRZEJCZYK W.:Przestrzenny model powierzchni bocznej zęba przekładni stożkowej", XV Conference of Computer Aided Design, October, 2005, Poland.

[5] SKAWIŃSKI P.: "Technological aspects of linking of milling teeth operation in Gleason and Klingelnberg systems", XIV Ukrainien–Polish Conference on "CAD in Machinery Design and Educational Problems" CADMD 2006, Polyana, Ukraine, 2006.

[6] SKAWIŃSKI P.: „Computer integrated design and manufacturing of spiral and hypoid bevel gears", XI International Conference "Computer Simulation in Machine Design – COSIM2006", Krynica Zdrój, August, 2006, Poland.

[7] WÓJCIK Z.: Przekładnie stożkowe, WNT 1984